Persistent Storage

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COMP2215: Computer Systems II
Persisten Storage on La Fortuna

- EEPROM → Databus
- Flash Memory → Programbus
- Secure Digital (SD) Card → SPI
EEPROM

Electrically Erasable Programmable Read-Only Memory

- Single memory cells can be written
  - in contrast to Flash
- Slow access
  - Parameter Storage
  - Code Tracing
- Limited number of write cycles
CMOS Floating Gate Transistors

Programming requires up to 20 V → stressing transistors

Microchip AN537
Speed vs. Endurance Trade-off

In the design of an EEPROM programming speed has to be traded against endurance.

- **Internal High Voltage**
  - increase: fast programming, low endurance

- **HV Ramp Rate**
  - increase: fast programming, low endurance

- **Oxide Thickness**
  - increase: slow programming, high endurance
Sample application: Telephone:

- Last number redial \(\rightarrow\) frequent writes
- Speed dial numbers \(\rightarrow\) rare writes

Small amounts of data, frequent writes:

\(\Rightarrow\) Ringbuffer
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Small amounts of data, frequent writes:

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EEPROM on AT90USB1286

- Size: 4 KB
- Endurance: $\geq 100k$ erase/write cycles
  - cycles for each byte
- Use Brown-out detection to avoid corruption
EEPROM on AT90USB1286

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- Endurance: $\geq 100k$ erase/write cycles
  - cycles for each byte
  - can be destroyed quickly with an 8 MHz clock
- Use Brown-out detection to avoid corruption
Flash Memory
Flash Memory

Flash memory is the most common non-volatile storage for embedded systems.

- It is (still) relatively expensive, but embedded systems usually do not have large amounts of memory.
- It is compact and robust
  - vibration
  - magnetic fields
  - dust
Flash Memory

- Very limited number of writes:
  - MLC flash with its 2-bits per cell:
    \[ \approx \ 5000 \text{ program/erase cycles} \]
  - TLC flash (3 layer cell NAND):
    \[ < \ 1000 \text{ program/erase cycles} \]
- Any number above this is virtual, not physical.
- Trade off in production cost between redundancy and lifetime.
Flash Access

- Read access to individual cells
- Write requires an erase cycle
- Erase is possible for block and sectors
- Sector erase allows pre-erasing of several blocks
File System: Physical Layer
On SD cards About 1% of capacity is reserved for DRM.

Wear levelling required to extend lifetime.
Mapping Logical addresses to physical addresses
Interface Protocol

3 Interface methods:

▶ 1-bit SD Bus
▶ 4-bit SD Bus
▶ SPI
Interface Protocol

3 Interface methods:
- 1-bit SD Bus
- 4-bit SD Bus
- SPI

SD Card

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
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<tbody>
<tr>
<td>1</td>
<td>CS</td>
</tr>
<tr>
<td>2</td>
<td>Dataln</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
</tr>
<tr>
<td>4</td>
<td>VDD</td>
</tr>
<tr>
<td>5</td>
<td>CLK</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
</tr>
<tr>
<td>7</td>
<td>DataOut</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
</tr>
</tbody>
</table>
Side Tour: Serial Communication
Serial Communication

- Point to point
- Bus
  - Master/Slave
  - Multi-master
    - Needs to deal with collisions
Serial Communication

- **Simplex**
  - one-direction only
    - like: Broadcast Radio

- **Half-Duplex**
  - bi-directional alternating
    - like: Amateur Radio, push-button microphone

- **Full-Duplex**
  - bi-directional at the same time
    - like: Telephone
Serial Communication

- UART/USART
  - like RS232, but watch for voltage
  - if asynchronous: needs good clock on each side
  - see also http://wormfood.net/avrbaudcalc.php/

- SPI (Serial-Peripheral interface)
  - full-duplex, hardware addressing, 10 MHz
Serial Communication

- **I²C** (Inter Integrated Circuit Communications)
  - ”two-wire protocol” (Data/Clock), 50 kHz
  - software addressing (127 nodes)
- **1-wire protocol**
  - half-duplex, master/slave
- **CAN**
  - reliable multi-master
- **USB**
SPI Protocol

- SPI
  /CS, SCK, MOSI, MISO,

- Write Protection
- Card Detection

8-Bit Microcontroller -> SDC/MMC-Slot
SPI Protocol

Reading in single block modus.
Reading blocks from the card

Send CMD16: Set block length 'optional'

Send CMD18: Continuously send blocks of data

Start byte received? Yes

Read data block, CRC value and add wait cycle

No

Next data block? Yes

Send CMD12: Stop transmission

No

CRC error occurred? Yes

Card error handling process

No
Picture Credit

Design Elektronik 10/2006